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(54) **Pyrolysis and combustion process and system.**

(57) A combustible solid material (10) is fed into the upper section of a pyrolysis chamber (16), thereby moving the material downward at a controlled rate through multiple stage zones (20,22,24,26) in said pyrolysis chamber, passing hot gaseous products of the partial oxidation of carbon char upward in countercurrent to the movement of said solid material in said pyrolysis chamber, driving off volatile matter in said solid material in a multistage equilibrium process, depositing carbon char in the lower section (30) of the pyrolysis chamber, introducing air (32) into the lower section of the pyrolysis chamber and partially oxidizing the char to form said hot gaseous products, removing ash and other non-combustible material (40) from the bottom of the chamber, removing a hot overhead fuel gas (42) comprised of the volatile matter from the solid material and the hot gaseous products of the partial oxidation of the carbon char, passing the overhead fuel gas to a combustion chamber (46) for combustion thereof with air (48), and applying the resulting hot combustion gases (50) exciting the combustion chamber to a heat load (52). Where the combustible solid material contains one or more acid components, the process also includes the step of passing the overhead fuel gas containing said components to a zone (60) containing a chemical adsorbent (59), and recovering a clean hot fuel gas (66) substantially free of the acid components for passage to the combustion chamber.

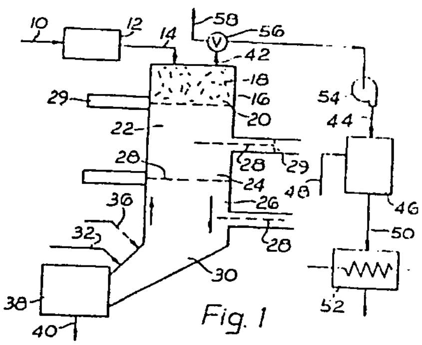

Fig. 1

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PYROLYSIS AND COMBUSTION PROCESS AND SYSTEM

This invention relates to pyrolysis of combustible solid material, and is particularly concerned with a process and system for efficiently pyrolyzing and then burning combustible solid material such as waste, e.g., industrial waste, for conversion of such solid material to heat, e.g. for driving a turbine or other heat load. The term "waste" as employed herein is intended to include, but is not limited to, industrial and household refuse, agricultural waste, feed lot and animal waste, unconventional fuels, biomass, and the like.

Industrial solid waste can be in the form of a combustible solid material of varying composition. A substantial proportion of such industrial waste can be primarily of a cellulosic nature such as scrap paper, cardboard, and the like. Other types of combustible industrial waste, such as for example rubber truck and automobile tires can contain acid components such as sulfur and chlorine.

Various processes have been developed heretofore for conversion of such combustible solid material, e.g. in the form of industrial waste, to heat for producing

energy. Such processes include pyrolysis of the combustible solid material to form a fuel gas containing carbon monoxide, and the combustion of such fuel gas to produce hot combustion gases for application to a heat load such as a turbine.

However, such prior art processes and systems suffer largely from being inefficient and uneconomical.

Further, where the combustible solid material such as industrial waste, e.g. in the form of automobile tires, contains acid components such as chlorine and sulfur, the resulting raw fuel gases from pyrolysis, containing such acid components present problems in connection with the further processing of such fuel gases.

Thus, if raw fuel gases containing unsaturated hydrocarbons components are cooled down, some condensation occurs and not only does the condensate polymerize and plug up the lines, but the energy in the fuel gases can be lost. Also, the acid components will be divided between the liquid and vapor phases, requiring two separate treatment processes for removal of acid components.

On the other hand, if the fuel gas were to be treated for removal of acid components after combustion, as common in present practice, there is a much greater mass of gas to be treated following combustion, and this

substantially increases the expense of the process.

One object of the present invention is the provision of an efficient and economical method and system for producing energy from combustible solid material, particularly waste material.

Another object is to provide a process for the controlled pyrolysis of pyrolyzable feed material to produce a fuel gas, affording flexibility to handle various feed material compositions, particularly derived from industrial waste.

A still further object of the invention is the provision of an efficient process for the pyrolysis of combustible solid material, particularly waste material which can contain acid components such as sulfur and chlorine, and cleaning the resultant hot fuel gas containing such acid components prior to combustion of the fuel gas, to avoid the above noted problems of the prior art practice.

The above objects and advantages of the invention are achieved according to two main features. One important feature of the invention is the provision of a counterflow, multistage pyrolysis procedure and system, and a second

important feature is the provision of a procedure and system for removal of pollutants and acid components or gases from the resultant hot fuel gas overhead from the pyrolysis reactor, at formation temperature in vapor phase on a chemical adsorbent.

Combustible solid material such as industrial waste, which may be essentially carbonaceous, and which may or may not contain acid components, is introduced into the upper section of a pyrolysis chamber. The solid material moves downwardly at a controlled rate through multiple stage zones in the pyrolysis chamber, which can be provided according to one preferred embodiment, by a series of moveable grates.

Hot gases, which are the products of partial oxidation of carbon char, occurring at the bottom of the pyrolysis chamber, pass upwardly in the pyrolysis chamber countercurrent to the downward movement of the solid material in the chamber. The moveable grates or other actuators which can be employed, tend to keep the solid material moving uniformly downwardly countercurrent to the upflow of the hot gases in the chamber. The rate of downward movement of the solid feed through each stage is such that equilibrium is substantially achieved in each

stage in the pyrolysis reaction between the solid combustible feed and the upwardly flowing hot combustion gases.

These hot gases drive off all volatile matter in the solid feed material and such volatile matter exits as overhead from the pyrolysis chamber in admixture with the gaseous products of the partial oxidation of the char. The resulting solid material from which the volatile matter was driven off, deposits as carbon char in the lower section or bottom of the pyrolysis chamber. Air or oxygen is introduced into the lower section of the pyrolysis chamber into contact with the carbon char therein, partially oxidizing the char to form hot gaseous products, which can comprise hydrocarbons, carbon monoxide and hydrogen. Such hot gaseous products then flow upwardly in the pyrolysis chamber into contact with the downwardly moving solid feed material, as described above. Ash and other non-combustible material is removed from the bottom of the pyrolysis chamber. Prior to such removal the ash and non-combustible material can be quenched.

The raw fuel gas which is removed as overhead and which can comprise hydrocarbons, carbon monoxide, hydrogen and nitrogen, is at a controlled elevated temperature, e.g. about 800°F to about 1,000°F. The temperature

of the overhead gas is controlled by controlling the flow rate of air into the carbon char for partial oxidation thereof.

If an excess of carbon char is deposited in the bottom of the pyrolysis chamber and temperature of the overhead is within a satisfactory temperature rnage, steam may be introduced into the carbon char, resulting in the water gas reaction forming carbon monoxide and hydrogen.

If acid components such as sulfur or chlorine are present in the solid feed material, the overhead gas from the pyrolysis chamber can be cleaned to remove such acid components and pollutants by contact in the hot vapor phase with a suitable chemical adsorbent. Such chemical adsorbent can be in the form of a bed, e.g. of calcium carbonate. The hot fuel gas exiting the pyrolysis chamber, or exiting the treatment zone containing chemical adsorbent where the pyrolysis gas contains acid components, is subjected to combustion, in air, and the resultant hot combustion gases are applied to a heat load, e.g. in the form of a turbine.

The invention thus provides an efficient multi-stage equilibrium pyrolysis process and system for the controlled pyrolysis of pyrolyzable feed material, and

in addition, the invention affords the additional feature of providing flexibility as by suitable chemical treatment of the hot fuel gas overhead with chemical reagents, for handling various feed material compositions which may contain undesirable pollutants or acid components.

A better understanding of the invention may be had by reference to the following description, taken in conjunction with the accompanying drawings in which:

Fig. 1 is a schematic flow sheet of the pyrolysis process of the invention for pyrolysis and burning of combustible solid material for the production of energy; and

Fig. 2 is a flow sheet illustrating a process and system according to the invention for the pyrolysis and burning of combustible solid material to provide energy, showing additional treatment of the overhead fuel gas from the pyrolysis zone with a chemical adsorbent, prior to combustion of the fuel gas.

Referring to Fig. 1 of the drawing, combustible solid material such as industrial waste is first prepared

as by shredding, for use as a feed material in the invention process. Such industrial waste can vary in composition and is preferably primarily a cellulosic material such as scrap paper, cardboard, wood chips, and the like.

The raw material or prepared refuse, indicated at 10 is first introduced into a feed-lock system at 12 for suitably feeding the raw material at 14 into the top of a pyrolyzer or pyrolysis chamber 16. The feed-lock system 12 is of any conventional type which prevents back-flow of gases from the top of the pyrolyzer.

The solid raw material 18 introduced into the pyrolyzer moves downward therein from the upper section of the pyrolysis chamber through four separate stages 20, 22, 24 and 26, in countercurrent flow to hot combustion gases passing upwardly in the pyrolyzer, and which are the products of partial oxidation of carbon char, occurring in the bottom of the pyrolysis chamber, as further described below.

In the downward movement of the feed material in the pyrolyzer 16, such material passes over a plurality of spaced grates 28 which are vertically disposed and horizontally moveable within the pyrolysis chamber 16, by means of actuators indicated generally at 29, such grates forming the above noted four vertically

positioned stages within the pyrolyzer. The moveable grates 28 tend to keep the solid combustible material 18 moving uniformly downwardly in the pyrolyzer at a controlled rate, and preventing plugging of the pyrolyzer while permitting uniform upward flow of hot gas through the downwardly moving solid mass, without channeling or formation of vapor pockets in the feed material, and achieving substantial reaction equilibrium at each stage, in the pyrolysis reaction.

Alternatively, in place of moveable grates, other moveable means can be used to provide controlled downward movement of the solid material in the pyrolysis chamber, for example a cylindrical column with a tray and wiper which moves the solid material to a weir over which the solid material flows for further downward movement. Other apparatus which performs the same function also can be employed.

In the pyrolysis chamber, which may have a temperature ranging from 2800°F at the bottom to 800°F at the top, the hot combustion gases passing upwardly from the bottom of the pyrolysis chamber and in contact with the solid combustible material passing countercurrently downward, drives off the volatile matter in the solid material and pyrolyzing it to carbon char which deposits at the

bottom of the pyrolysis chamber. Thus, as the hot gases move upwardly all of the volatile materials in the raw feed material, which can include hydrocarbons such as methane and heavier hydrocarbons, are vaporized from the incoming material.

The solid product of the pyrolysis reaction deposits in the lower section or bottom 30 of the pyrolysis chamber. Air or oxygen is introduced at 32 into the char in the bottom of the pyrolysis chamber, which partially oxidizes the carbon char so that the resulting hot gases are comprised of a mixture of carbon monoxide (CO), hydrogen and nitrogen. The overhead which exits the top of the pyrolysis chamber at 42 thus consists of a mixture of the hot partial oxidation combustion gases, together with the volatile gases given off from the solid feed material, and comprising a mixture of hydrocarbons of varying molecular weights ranging from methane to decane, carbon monoxide, hydrogen and nitrogen. The raw fuel gas which thus exits the top of the pyrolyzer can have a temperature ranging, for example, from about 800°F to about 1,000°F.

The partial oxidation air introduced at 32 in the bottom of the pyrolysis chamber is controlled on the basis of the temperature of the overhead fuel gas. If an excess

of carbon char is present at the bottom of the pyrolyzer and the temperature of the overhead fuel gas is in the proper temperature range, as noted above, steam may be added at 36 to the carbon char, resulting in the water gas reaction and forming CO and hydrogen.

Ash and other non-combustible material resulting from the partial oxidation of the carbon char in the bottom of the pyrolysis chamber is quenched at 38 by introducing water, and the resulting quenched material is then removed at 40 from the bottom of the pyrolysis chamber.

The raw hot fuel gas overhead at 42 from the top of the pyrolysis chamber is then introduced at 44 into a combustion chamber 46 of any suitable type and the hot fuel gas therein is then subjected to combustion by the introduction at 48 of excess air or oxygen into the combustion chamber.

The resulting hot combustion gases exiting the combustion chamber at 50, and at a temperature of about 1,600°F to about 1,700°F, is introduced into a heat load, indicated at 52, which can be in the form of a down-fired gas turbine, a boiler or other heat load.

A blower 54 is provided at a suitable point in the system, for example between the pyrolysis chamber 16 and the combustion chamber 46, to maintain a slight

negative pressure in the pyrolysis reactor, to prevent leakage of noxious vapors. Where a source of compressed air is available an ejector alternatively can be employed for this purpose.

If desired, the fuel gas overhead 42 from the pyrolysis chamber can pass through a diverter valve 56 which can operate on hydraulic pressure so that if the pressure of the overhead fuel gas at 42 becomes excessive due to a malfunction or failure in the system, the fuel gas can be diverted at 58, and can be stored or burned.

Now referring to Fig. 2 of the drawing, the system shown therein is employed according to the invention, where the raw feed material consists essentially of a cellulose material and contains pollutants, e.g. in the form of one or more acid constituents such as sulfur and chlorine, as for example industrial waste in the form of scrap truck and automobile tires, which can contain acid components such as sulfur and chlorine. As previously noted, cooling of the fuel gas from the pyrolysis chamber prior to treatment thereof for removal of pollutants and acid components, can result in disadvantageous condensation of the fuel gas, or if the hot gases following combustion are treated for removal of pollutants and acid components, as heretofore practiced,

this is disadvantageous because the resulting gas mass to be treated can be of the order of 15 times greater than the mass of the hot fuel gas before combustion. Thus, as shown in Fig. 2, according to the present invention, the raw overhead fuel gas at 42 from the pyrolysis chamber 16 is cleaned by introducing same into a bed of a chemical adsorbent 59 in an adsorbent chamber 60, into which the chemical adsorbent is introduced at 62. The chemical adsorbent can be calcium carbonate, or any other acid adsorbent such as bentonite or sodium carbonate.

The bed of chemical adsorbent can be in the form of a continuous feed system, with spent reagent removed at 64 from the bottom of the treating chamber 60, via a spent reagent lock at 65, or in the form of a dual stationary bed system (not shown).

The resultant clean fuel gas at a temperature of about 800 to about 1,000°F is then passed at 66, and via the blower 54, into the combustion chamber 46. The resulting hot combustion gases are then applied to a heat load 52, as described above.

The following is an example of practice of the present invention:

According to the invention process and system as illustrated in Fig. 1 and described above, combustible

shredded waste is processed utilizing about 50 tons per day, which produces on the average 4,500 Btu per pound, of energy.

The bottom of the pyrolysis chamber operates at a temperature of about 2,800°F, with an input of about 180 moles per hour of air at 800°F into the bottom of the pyrolyzer.

Overhead combustible gas at a temperature of about 1,000°F exits the top of the pyrolyzer in an amount of about 275 moles per hour. The combustible gas is introduced into an ejector, into which is also introduced air at 4 atmospheres pressure and 1,400°F in an amount of 20 moles per hour. The ejector maintains a slight negative pressure in the pyrolysis chamber.

The raw hot fuel gas exiting the ejector and at a slight positive pressure is introduced into a combustion chamber. Combustion air at 800°F and in an amount of about 3,400 moles per hour is fed to the combustion chamber.

Hot combustion gases at a temperature of 1,600°F exit the combustion chamber and are passed to a heat exchanger, to extract about 18 million Btu per hour of energy.

From the foregoing, it is seen that the invention provides an efficient counterflow, multiple-stage pyrolysis process and system for conversion of combustible solid material to a hot fuel gas, and also provides a process and system for removal of pollutants and acid gases from the hot fuel gas by chemical adsorption on a solid reagent. The process and system of the invention successfully pyrolyzes and then burns combustible solid material, particularly industrial waste, in a manner which provides the highest efficiency, is extremely simple to control and can be made environmentally acceptable.

CLAIMS

1. A process for pyrolysis and combustion of combustible solid material which comprises

introducing combustible solid material into the upper section of a pyrolysis chamber,

moving said material downwardly at a controlled rate through multiple stage zones in said pyrolysis chamber,

passing hot gaseous products of the partial oxidation of carbon char upwardly countercurrent to the movement of said solid material in said pyrolysis chamber, and driving off volatile matter in said solid material in a multistage equilibrium process,

depositing carbon char in the lower section of the pyrolysis chamber,

introducing air into the lower section of said pyrolysis chamber and partially oxidizing said char to form said hot gaseous products,

removing ash and other non-combustible material from the bottom of said chamber,

removing a hot overhead fuel gas comprised of said volatile matter from the solid material and the hot gaseous products of the partial oxidation of the carbon char,

passing said overhead fuel gas to a combustion chamber for combustion thereof with air, and

applying the resulting hot combustion gases exiting the combustion chamber to a heat load.

2. A process according to Claim 1, including passing said combustible solid material through a feed-lock system prior to the introduction of said solid material into said pyrolysis chamber.

3. A process according to Claim 1 or 2, including controlling the temperature of the overhead gas by controlling the flow rate of air for the partial oxidation of said char.

4. A process according to any of Claims 1 to 3, said multiple stage zones being provided by a series of spaced vertically disposed horizontally movable grates in said pyrolysis chamber.

5. A process according to any of Claims 1 to 4, including depositing an excess of carbon char in the lower section of said pyrolysis chamber and introducing steam into said carbon char to carry out a water gas reaction, and forming CO_2 and H_2.

6. A process according to any of Claims 1 to 5, wherein said combustible solid material contains one or more acid components, and including passing the overhead fuel gas containing said components to a zone containing a chemical adsorbent, and recovering a clean hot fuel gas substantially free of said acid components, for passage to said combustion chamber.

7. A process according to any of Claims 1 to 5, wherein said combustible solid material is a combustible solid industrial waste comprised essentially of cellulosic material, and resulting in the production of a hot overhead fuel gas comprising hydrocarbons, CO, H_2 and N_2.

8. A process according to any of Claims 1 to 7, including quenching the ash and other non-combustible material in the bottom of said pyrolysis chamber prior to removal thereof.

9. A process according to Claim 6, wherein said combustible solid material is a combustible solid industrial waste comprising essentially a cellulosic material containing an acid component selected from the group consisting of S and Cl, the overhead fuel gas comprising hydrocarbons, CO, H_2, N_2 and said acid component.

10. A process according to Claim 7, wherein the hot overhead fuel gas has a temperature ranging from about $800^{\circ}F$ to about $1,000^{\circ}F$, and said hot combustion gases

exiting the combustion chamber having a temperature ranging from about 1,600°F to about 1,700°F.

11. Apparatus for pyrolysis and combustion of combustible solid material which comprises

a pyrolysis chamber,

means for introducing a combustible solid feed material into the upper section of said pyrolysis chamber,

means forming a plurality of zones in said pyrolysis chamber and permitting downward movement of said solid material at a controlled rate through said zones countercurrent to the upward flow of hot gaseous products of the partial oxidation of carbon char, and driving off volatile matter in said solid material by a multistage equilibrium operation,

means for introducing air into the lower section of said pyrolysis chamber into contact with carbon char deposited therein from said solid material, for partially oxidizing said carbon char, and forming hot gaseous products,

means for removing ash and other non-combustible material from the bottom of said chamber,

means for removing a hot overhead fuel gas from said pyrolysis chamber,

means for introducing said overhead fuel gas into a combustion chamber,

means for introducing air into said combustion chamber for combustion of said fuel gas therein,

a heat load, and

means for applying the resulting combustion gases to said heat load.

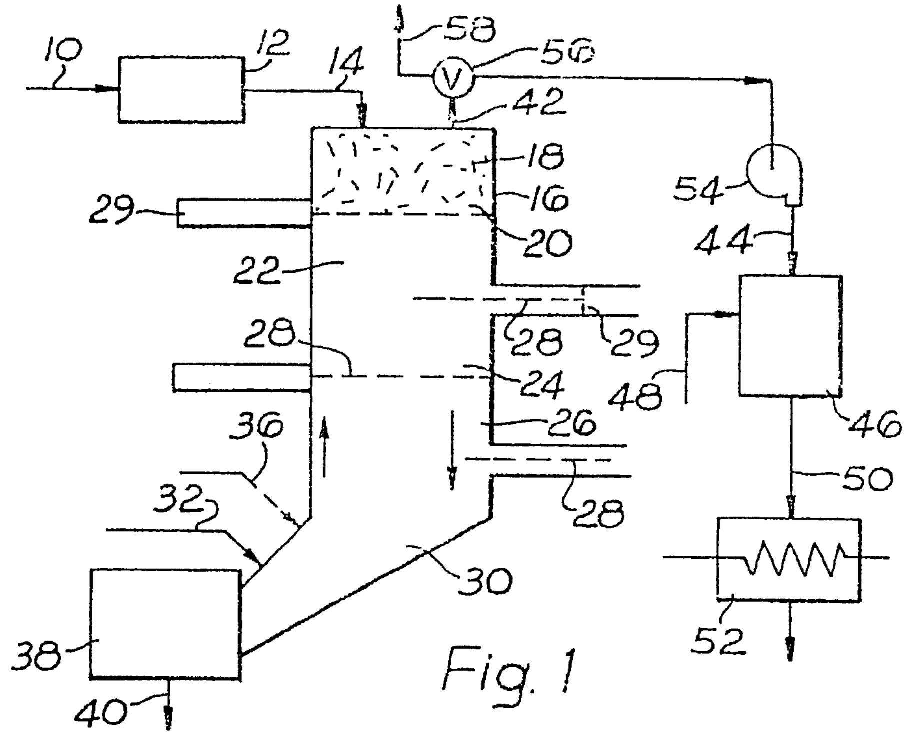
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Fig. 1

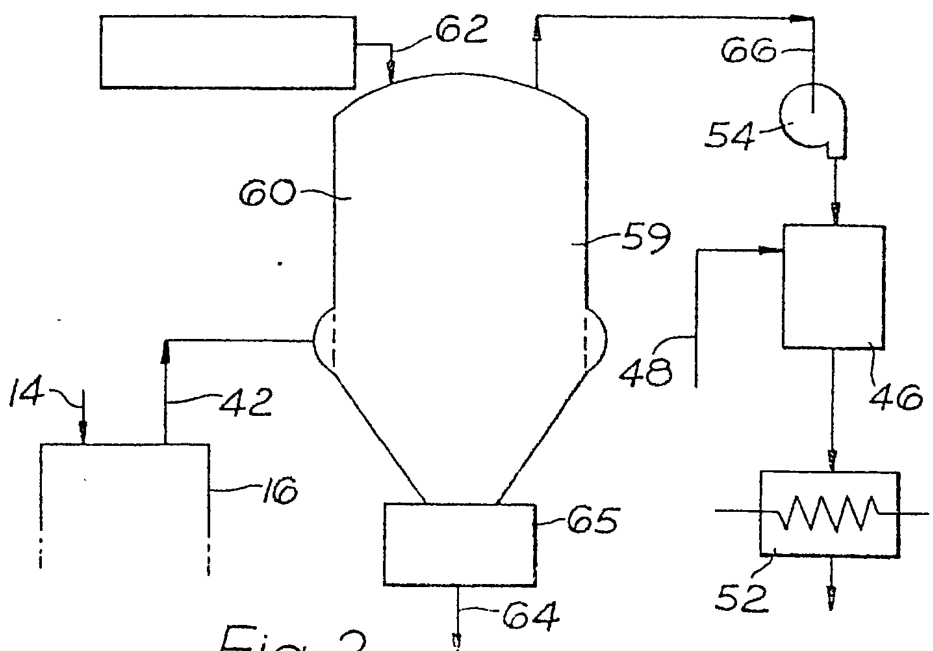
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Fig. 2

European Patent Office

EUROPEAN SEARCH REPORT

0224999
Application number

EP 86 30 7075

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int Cl 4)
X	EP-A-0 072 387 (ONAHAMA SEIREN) * Claims 1-4; figure 1 *	1-4,8, 11	C 10 B 53/00 F 23 G 5/027 C 10 J 3/66
X	FR-A-2 104 443 (EBARA INFILCO) * Claim 1; figures 1,2 *	1-10	
A	DE-A-2 930 256 (BALSTER) * Claims 1-13; figure *	1-11	
A	EP-A-0 040 857 (DEUTSCHE KOMMUNALANLAGE MIETE) * Claims 1,5,6; figure 1 *	6-9	

TECHNICAL FIELDS SEARCHED (Int Cl 4)

C 10 B
C 10 G
C 10 J
F 23 G

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	27-01-1987	MEERTENS J.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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